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"Contribution to Working Group 1: Definition of cognitive algorithms for adaptation and configuration of a single link according to the status of external environment."

Distributed Runtime Synchronization for 5G small cells

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A dense uncoordinated deployment of small cells is targeted by a novel 5th Generation (5G) radio access technology (RAT), which is expected to take place in the mass market around 2020 to cope with the exponential increase of the data rate demand [1]. Network synchronization among multiple neighbor Access Points (APs) is considered as an important enabler for interference management techniques, whose usage can significantly boost the cell throughput in such a dense scenario. In the current cellular networks time synchronization among multiple base stations is typically achieved by relying on the timing signals transmitted by the GPS satellites. However, penetration losses to indoor may significantly reduce the accuracy of such reference for indoor small cells deployments. Distributed synchronization solutions, where the APs autonomously agree on a common timeline without centralized coordination, are then to be pursued for our 5G RAT.

In an air interface based on Orthogonal Frequency Division Multiplexing (OFDM), the targeted synchronization accuracy is typically in the order of a fraction of the Cyclic Prefix (CP) duration, such that coherent data demodulation can be performed [2]. For efficiency reasons, in 5G the CP duration is set to be 1 μs, leading to a very ambitious synchronization accuracy target.

We distinguish between the initial synchronization problem –how to first achieve time alignment among multiple nodes- and the runtime synchronization problem – how to maintain the nodes synchronized despite of the non-idealities of the hardware clocks.

The presentation focuses on the distributed runtime synchronization for 5G small cells, with the aim of verifying its suitability in achieving the ambitious accuracy target.

By assuming that a first time alignment has already been achieved, synchronization at network level can be maintained by ensuring beacon messages exchange among the nodes. This raises the problem of an efficient decentralized scheduling of the beacon messages such that each network node can be informed on the timing of its neighbors. We propose a simple random scheduling solution where at every inter-beacon time each node can decide whether transmitting its beacon message with a certain probability p, or receiving eventual beacons sent by its neighbors. This allows to distribute the timing of the nodes across the network without any centralized coordination.

As mentioned above, even in case a first time alignment is already acheived, the nodes timings may soon diverge due to the non-idealities of the hardware clocks; upon reception of a beacon message, each node should compare its internal timing with the timing of the neighbor, and perform a correction such that the time alignment can be maintained.

Two clock correction techniques are evaluated:

- Additive clock update; it basically modifies only the phase of the local clock.
- Multiplicative clock update; it modifies both phase and frequency of the clock, and it is inspired to the algorithm in [3].

Performance is evaluated in a local area 3GPP-inspired scenario with 40 cells of apartment [4], by assuming different deployment ratios (DRs), i.e. different probabilities of having an AP at each apartment. We further assumed clocks having nominal precision of 1 part-per-million (PPM) and a 10 ms periodicity of the inter-AP beacon exchange. Figure 1 shows the Cumulative Distribution Function (CDF) of the residual time misalignment between different APs; in 90% of the cases it is possible to achieve a residual error below 200 ns even for DR=100%, and then significantly lower than our requirement.

Our current activities are focused on the design of a software defined radio (SDR) testbed based on the USRP hardware by Ettus Research aiming at the proof-of-concept of the discussed distributed synchronization solutions. The testbed is designed by using the Asgard software platform developed at Aalborg University [5]. Figure 2 represents a preliminary result in terms of timing misaligment in a simple network with 3 nodes, using the additive clock update mechanism. Note that the absolute magnitude of the residual misalignent is larger than the aforementioned target due to the obvious hardware/software limitations, but it is maintained constant over time, confirming the validity of the discussed solution.

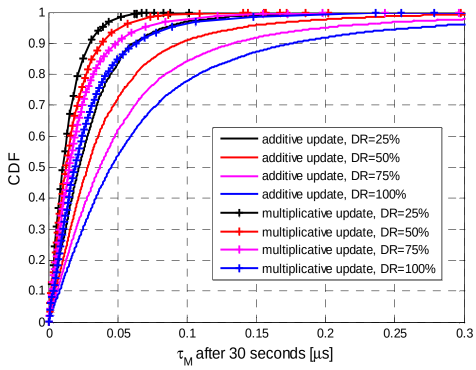

Figure 1. Distribution of residual time misalignment between neighbor nodes.

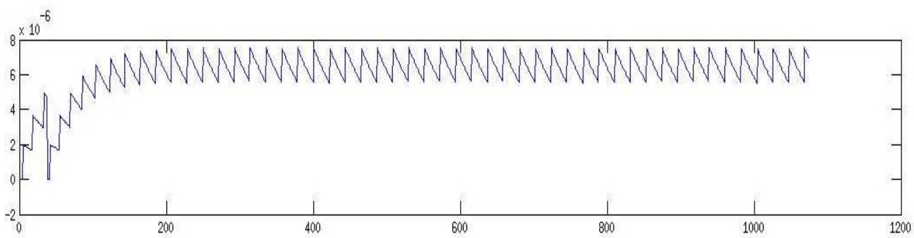

Figure 2. Measured misalignment over time in a 3 nodes scenario.

[1] P. Mogensen *et al.*, “Beyond 4G local area: high level requirements and system design,” accepted in Globecom 2012, International workshop on emerging techniques for LTE-Advanced and Beyond 4G.

[2] L.Hanzo, M. Munster, B.Choi, T.Keller, “OFDM and MC-CDMA for broadband MultiUser Communications, WLAN and Broadcasting”. John Wiley – IEEE Press, 2003.

[3] C.H.Rentel, and T. Kunz, “A mutual Network Synchronization Method for Wireless Ad Hoc and Sensor Networks”, IEEE Transactions on Mobile Computing, vol.8, no.5, May 2008.

[4] “Simulation assumptions and parameters for FDD HeNB RF requirements”, 3GPP TSG RAN WG4, Tech. Rep. R4-091422, March 2009.

[5] "ASGARD," 2012. http://asgard.lab.es.aau.dk.